Geoenvironmental Breakout Session

The INEEL hosted a Workshop on general the general principles of research that utilizes high gravity environments available in geocentrifuges, and applications to a wide range of geotechnical and environmental problems. A breakout session was held to focus specifically on geoenvironmental research topics. This session, lead by Dr. Carl Palmer, began with four 15-minute talks highlighting environmental research topics that are currently being addressed through the use of the INEEL's geocentrifuge. After these talks, an open discussion was held where the pros and cons of a geocentrifuge were explored as well as potential applications for a wide variety of topics. A summary of the geoenvironmental breakout session follows.

Fluid Flow and Unsaturated Flow Properties in a Centrifugal Field
Dr. Carl D. Palmer (INEEL)
Carl opened the series of talks with a review of proposed scaling rules used in the centrifugal hydrologic investigations. This review suggested that there are two appropriate scaling methods depending on the uses of the centrifuge data. If the scale of the centrifuge model is the same as the "real-world prototype" under an acceleration of "n" time the acceleration of gravity, then time scales as a function of "n". If the length of the centrifuge model is a scaled model of the prototype is scaled by "n", time scales as n^2. Carl suggested that a valuable application for the geocentrifuge would be in the study of changes in the pore size distributions caused by a number of mechanisms such as microbial plugging, precipitation reactions, and the development of *in-situ* reactive barriers. Numerical codes for vadose-zone flow and transport (HYDRUS 1-D and HYDRUS 2-D) have recently been modified to simulate behavior in a centrifugal field. Carl finished the talk with a discussion of more fundamental theory of fluid flow in porous media in the geocentrifuge and the incorporation of these theories to understand processes within a centrifuge experiment as well as to design experiments.

Coupled Flow and Reactivity in Variably Saturated Porous Media
Dr. Robert W. Smith (University of Idaho)
Bob expanded the geoenvironmental research theme through a discussion on chemical reactive transport applications using a geocentrifuge. This talk was based on a currently funded EMSP project that suggests that the chemical distribution coefficient is a function of moisture content rather than a simple constant. The water-mineral contact area, and even which minerals are contacted, will not be a simple linear function of moisture content. This means that the currently accepted dependence of K_d on moisture content is incorrect and will affect predictions of solute transport time through unsaturated materials. The proposed theory suggests that the chemistry terms can be separated from the physical parameters terms. The geocentrifuge allows us to an opportunity to test this hypothesis in a much shorter time and at much lower moisture contents than conventional column experiments.

Nonaqueous Phase Liquids
Dr. Hideo Nakajima (INEEL)

Hideo discussed multiphase issues within a centrifuge experiment. Using a portion of his dissertation work at the University of California, Davis, Hideo highlighted some of the macroscopic and microscopic scale lengths important to geocentrifuge testing. He cautioned that although higher accelerations will result in shorter experimentation time, the cost is in the greater difficulty in controlling boundary conditions and maintaining measurement quality. Potential applications of the geocentrifuge include NAPL flow in heterogeneous soil and the study of seawater intrusion, applications that centrifuge can be used to mimic phenomena in large scale. He concluded his talk by comparing his centrifugal experimental results with numerical predictions using STOMP.

Colloids, Coupled Processes, Contaminant Transport, and Geocentrifuges
Dr. George Redden (INEEL)
George concluded the set of summary talks with a discussion of centrifugal application to better understand colloid transport. His discussion briefly reviewed the principles of colloid facilitated transport in porous media, and mechanisms by which colloids are immobilized by physical filtration and interactions with mineral surfaces. This topic has become important in geoenvironmental research as a way to explain the apparent enhancement of contaminant transport in porous media and the potential of using colloids for remediation. George suggested that the centrifuge could be used to examine fundamental issues of colloid filtration mechanisms where current model simplifications assume single modes of particle trapping and re-mobilization. The geocentrifuge also offers the capability to study colloid partitioning and transport under unsaturated conditions, and in response to perturbations in solution composition and flow rates.

Open Discussion
Following the brief presentations an open discussion was held in which a number of issues were raised. The major themes of the discussion are briefly described in the following bullets.

- It was generally agreed that application of the geocentrifuge to geoenvironmental issues is not as mature as the geotechnical applications. Much of the current geoenvironmental work has examined centrifuge-scaling issues similar to those being used in the geotechnical field. However, while the geotechnical community goals are to recreate scaled physical models of stress fields within the geocentrifuge, the geoenvironmental community is more interested in accelerating advective transport for the purpose of shortening the time needed to conduct experiments, and to investigate the effects of high flow rates.
- Results from geoenvironmental centrifuge studies need to be published in the “main stream” technical literature not limited to centrifuge conferences and journals. Through prompt publication, centrifuge techniques will move from a novelty to another accepted experimental tool for investigating subsurface environmental phenomena.
- The main challenge is to move from centrifuge scaling issues toward using the centrifuge to increase the driving force of advective flow. In unsaturated systems this increased driving force will allow for experimentation in lower moisture

content regimes than are practically obtainable using traditional soil-physics methods.

- An often-overlooked advantage of centrifuge methods is the potential to decouple processes. If diffusion and chemistry can be decoupled from advection processes it will be possible to examine unsaturated transport issues in more unique ways, improve our conceptual models, and test models against experimental data.
- Several additional issues were discussed such as the effects of continuous verses discontinuous phases with an enhanced acceleration field, microbiological physiological effects, creating geologic structures, and geoengineering of materials.

Concluding Remark

The use of a geocentrifuge is currently viewed as a non-traditional experimental technique. Nonetheless, its ability to decouple processes and enhance the driving advective flow field offers a unique methodology to examine processes in moisture ranges not practical using traditional laboratory experimentation techniques and to complete experiments in much shorter periods of time. The latter point is important with respect to the need to test a wide range of system conditions when conceptual models are not well developed or entirely lacking. The challenge to the geoenvironmental community is identify applications that most effectively take advantage of the unique aspects of the geocentrifuge.